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SOIL FERTILITY CAPABILITY CLASSIFICATION AS MANAGEMENT OPTIONS TO REMEDIATE PLANT GROWTH AND PRODUCTION RELATED CONSTRAINTS OF SOME SUBTROPICAL SOILS ON VARYING PARENT MATERIALS AND ALTITUDE

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ABSTRACT

Soil fertility capability classification (SFCC) was evaluated as management options for plant growth and production related constraints of some subtropical soils developed on varying parent materials and altitude occurring in three geomorphic erosion surfaces of west Bengal and Jharkhand state of India. Representative surface and sub-surface samples from Kharagpur, Garbeta, Kurchiboni, Silda, Labani, Bara Ara, Lalgutuwa, Netarhat, Bagru soils developed respectively on Alluvium, Alternate cross-bedded sandstone and shale, Calc-schist admixed with detrital laterized material, Basic / Calc-schist, Phyllite, Meta-amphibolites (gabbro), Granitic-gneiss, Basic (Deccan trap) and Granite parent material at 50, 150, 215, 234, 245, 275, 590, 1037, 1050 m altitude were studied in respect of SFCC along with established condition modifiers such as, (i) dry condition 'd', (ii) Low cation exchange capacity 'e', (iii) aluminum-toxicity 'a', (iv) high P-fixation by iron 'i', (v) Low K reserves 'k', (vi) Gravel, a prime (') denoting 15-35% gravel and texture two prime marks ('') denoting > 35 % gravel and local biological soil condition modifier 'm'. The SFCC units identified for different soils, were LLaeihm (0-2%) to LLaikm (0-2%) for Kharagpur, L''L'' adeim (3-4%) to L''L'' adeikm (3-4%) for Garbeta, L'C ^^ ad (2-3%) to L'C ^^ adim (2-3%) for Kurchiboni, LC vd (1-2%) to LC vm (1-2%) for Silda, L''L^^ dh (3-4%) to L''L^^ dhim (3-4%) for Labani, C"C' gi (2-3%) to C"C' m (2-3%) for Bara Ara, C ^^ C"dheik (3-5%) for Lalgutuwa, LLgv (8-10%) to LLv (8-10%) for Netarhat, LC egiaek (0-2%) to LCeik (0-2%) for Bagru. Results clearly indicated wide variations of management options for combating various plant growth and production related constraints for soils developed on varying parent materials and altitude.

KEYWORDS: Subtropical Soils, Varying Parent Materials & Altitude, Soil Fertility Capability Classification, Constraints, Management Options

INTRODUCTION

The concept of soil fertility capability classification (SFCC) system was developed as an attempt to bridge the gap between sub-disciplines of soil classification and soil fertility, especially to interpret soil taxonomy and additional soil attributes in a way that is directly relevant to the plant growth (Buol *et al.* 1975; Buol and Couto, 1981; Sanchez *et al.* 1982; Denton *et al.* 1987; Zehetner and Miller, 2006; Geissen *et al.* 2009). The use of different soils for agriculture purposes of suitable management practices needed, mainly depend on variability in soil for maximizing the agricultural production. Soil fertility management at optimum level is the most important single factor for sustainable and time-demanding management practices. The SFCC is a classification of soil on the basis of constraints, quantified from condition modifiers (Rao and Jose, 2003). The utility of SFCC is thus straight, grouping the soils of similar production constraints together. In addition a huge amount of data is needed to be generated for classification by conventional soil

taxonomy whereas SFCC system requires less information about the production constrains. There was no indication of soil organic matter (SOM) content (except for O soils) in the original version of SFCC which was modified later on to include specific interpretation for wetland rice Soil (Buol, 1986; Sanchez, 1997) and biological soil condition modifier ‘m’ by Sanchez *et al.* (2003) by using the concept of organic carbon saturation deficit (Hassink, 1997; van Noordwijk *et al.* 1997) which is the ratio of present topsoil total SOC level to the SOC level in the soil in its undisturbed state. The threshold value is the per cent carbon (% C) saturation at which the soil is reaching limits in items of its capacity to maintain many of its functions. Sanchez *et al.* (2003) proposed a value of 80% of the original topsoil total soil organic carbon as a trial indicator that the soil reaching a threshold in terms of its capacity to maintain many of its functions. They also opined that modifier ‘m’ should be measured alternatively by $KMno_{4}$ - extractable C method as proposed by Blair *et al.* (1997). In the present study SFCC (including modifier ‘m’ as specified by Sanchez *et al.* 2003) of some subtropical soils developed on varying parent materials and altitude in west Bengal and Jharkhand state have been evaluated as management options of these soils for plant growth and production related constraints.

MATERIALS AND METHODS

The area of about 16000 Km^{2} lying between north latitude of $22^{0}15'$ and $23^{0}45'$ and east longitude of $84^{0}0'$ and $87^{o}30'$, forming parts of Ranchi and Palamau districts of Jharkhand state through Purulia and farther to the western fringe of West Bengal in Medinipur district as a terrain of aluminous laterite/ lateritic soil to low level lateritic soils, was taken under present study. Climatologically the area falls tropical climate prevailing over the high altitude hilly areas and sub-humid tropical to subtropical climate at lower elevations. South westerly monsoon prevails over the entire area of higher altitude for about four months from the middle of June to middle of October, with a few occasional showers during the month of January and February and some thunder showers in April –May. Average rainfall at higher altitude is about 1300mm, while the same at lower altitude varies from 1200-1500mm, of which about 800mm comes from south-west monsoons falling during July to October. At higher altitude the maximum temperature during summer is over 40^{0}C and the minimum temperature lies between 3 and 4^{0}C, while at lower altitude temperature varies from 7^{0} C to 46^{0} C between the coldest and the warmest month of the year. According to Niyogi (1987) soils in this area have developed on three stepped erosional geomorphic surfaces, 1) Netarhat – Bagru surface (oldest and at altitude around 1050 m, msl), 2) Ranchi surface (intermediate, at 700 m, msl) and 3) Purulia – Kharagpur surface (the youngest and the lowest at 265-50 m, msl). The altitude plays a role in changing the nature of the plants/ vegetation which is characterized by tropical to subtropical deciduous to semi-deciduous forest of degraded nature. The parent materials of the area are chiefly of Archaean era containing granite, granitic gneiss, phyllite and phyllitic-schist, calc-Schist/mica-schist, meta amphibolites (gabbro), basic parent material, tertiary sediments of alternating sandstone and shale and alluvium. Surface and subsoil samples were collected from representative pedo-geological pedons developed at Kharagpur, Garbeta, Kurchiboni, Silda, Labani, Bara Ara, Lalgutuwa, Netarhat, Bagru respectively on Alluvium, Alternate cross-bedded sandstone and shale, Calc-schist admixed with detrital laterized material, Basic/ Calc-schist, Phyllite, Meta-amphibolites (gabbro), Granitic-gneiss, Basic (Deccan trap) and Granite parent material at 50, 150, 215, 234, 245, 275, 590, 1037, 1050 m altitude in chronological order.

Pedons were studied for detailed morphological (FAO, 1996) and physico- chemical characteristics using standard procedures. The analyzed parameters were soil texture, soil colour, pH, electrical conductivity (EC), sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{2+}), and magnesium (Mg^{2+}) ions, cation exchange capacity (CEC), exchangeable sodium

percentage (ESP) and soil organic carbon (SOC). The Soil texture was determined by international pipette method (Piper, 1966) and textural classes were determined by using USDA textural triangle. Soil colour was measured by using Munsell colour chart. Soil pH was measured by pH meter with glass electrode (Richards, 1954). The electrical conductivity was determined by using EC meter (Richards 1954). Sodium and potassium concentrations were determined using ELICO CL- 220 flame photometer (Jackson, 1967). Calcium and magnesium concentrations were determined by titration method using ethylene diamine tetra-acetic acid (EDTA) (Borrows and Simpson, 1962). Cation exchange capacity was determined by neutral normal ammonium acetate method (Richards 1954). The ESP was computed by using the formula from the United States Salinity Laboratory (Richards 1954). Soil organic carbon (SOC) was determined by Walkley and Black (1934) rapid titration method. The soils were classified according to soil taxonomy (Soil Survey Staff, 1999)

Development of SFCC

SFCC system consists of three categorical levels: type (texture of upper 20 cm of surface soil), sub – strata type (sub-soil texture between 20 and 50 cm depth), and condition modifiers (physical and chemical properties which influence the interaction between soil and fertilizer materials). The type levels are of four types: sandy top-soils (S), loamy top-soils (L), clayey top- soil (C) and organic top-soils (O). Similarly, the sub -strata type levels are also of four types: sandy sub-soils (S), loamy sub-soils (L), clayey sub- soil (C) and rock or other hard root restricting layer (R). Apart from fifteen condition modifiers of original version of SFCC i.e. gley (g), dry (d), low CEC (e), aluminum toxicity (a), acid (h), high P fixation by iron (i), X-ray amorphous (x), Vertisol (v), low K- reserves (k), basic reaction (b), salinity (s), natric (n), cat clay (c), gravel 15-35% (‘) and >35% (“) and slope (%), a biological soil condition modifier (m), proposed by Sanchez *et al.* (2003) was used in this study to address the growing need of the farmers of this sub-tropical regions for maintaining productivity and sustainability.

RESULTS AND DISCUSSIONS

The average values of soil physical, physicochemical and chemical properties used to identify different characteristics of soils developed on varying parent materials at varying altitude on three stepped erosional geomorphic surfaces are presented in Table 1 A and 1 B. Results revealed that depending upon parent materials and altitude gravel per cent varied both in surface and sub-surface of all the soils and texture (< 2mm) varied from sandy clay loam to clay (Table 1 A). Dry soil colour varied widely from higher altitude to lower altitude depending upon parent materials, rainfall coupled with degree of weathering. Surface and sub- surface soils were neutral to strongly acidic in reaction, where surface soil (0 – 20 cm) of Bara Ara and Garbeta exhibited respectively the highest(6.6) and lowest soil pH(4.1). All the soils were non-saline in nature. Exchangeable Ca^{++} and Mg^{++} as well as CEC were higher in soils developed on basic / calc-schist/ meta-amphibolite parent materials at Slida, Netarhat and Bara ara as compared to those of others (Table 1 B). Soils having CEC<10 indicated presence of higher percent of 1:1 type clay, where as CEC > 30 or so indicated presence of higher percent of 2:1 type clay and CAC with intermediate value pointed to the presence of mixed type of clay minerals. ESP of soils were either very low or negligible. Soil organic carbon content of Khadakpur, Garbeta for both the soil depth and of Kurchiboni, Silda, Labani and Bara Ara for sub surface soil depth was low, while the same for Lal gutawa and Netarhat soil was medium (Table 1 B). Depending upon soil pH, irrespective of parent materials and altitude, total acidity, aluminum acidity and exchangeable H^{+} acidity, differ to appreciable extent from soil to soil.

Based on these analytical data the soils were classified into different SFCC units based on Type, Substrata type and condition for each of the region/ place. The condition modifiers relevant to the area were - (i) dry condition ‘d’ having

ustic moisture regime (ii) Low capacity ‘e’ having CEC< 7 cmol$(p^+)kg^{-1}$ of soil at pH 7. (iii) A = aluminum-toxicity ‘a’ with > 60% A1-saturation of the effective CEC within 50 cm of the soil surface. (iv) high P-fixation by iron ‘i’ having % free % free Fe2O3/% clay > 0.15 and more than 35% clay (v) low K reserves ‘k’ having exchangeable K < 0.20 me /100 g. (vi) Gravel: a prime (‘) denotes 15-35% gravel or coarser (> 2 mm) particles by volume to any type or substrata type texture two prime marks (‘’) denote more than 35 % gravel or coarser particles (> 2 mm) by volume in any type or substrata type. % = (slope): where it is desirable to show slope with the FCC, the slope.

SFCC

The role of slope in soil formation needs not be emphasized which also is expected to influence the type, substrata type and condition modifiers thus FCC in turn. Based on the criteria suggested by Sanchez *et al.* (1982) and Sanchez *et al.* (2003), Kharagpur soils on alluvium have been placed under SFCC class LLaeihm (0-2%) to LLaikm (0-2%) which characterizes (a) soils are situated at 2-3% slope and with sandy clay loam texture (b) surface and subsurface-soil deficient in organic carbon which necessitates addition of sufficient quantum of organic manure / matter, (c) comparatively low ability to retain nutrients against leaching, mainly K, Ca and Mg calling for high dose application of these nutrients with split application of N fertilizers, (d) low to medium soil acidity with occasional aluminum toxicity, requires liming for Al-sensitive crops, (e) P-fixation capacity is not very high, occasionally requiring special P management practices, (f) K-reserves or available K marginal and requires monitoring through frequent application of K-fertilizers.

The soils of Garbeta situated at 3-4% slope and developed on cross-bedded sandstone-shale have been placed under L’’L'' adeim (3-4%) to L’’L'' adeikm (3-4%) which characterizes (a) Gravelly texture (>35% Gravel) both at surface and sub-surface horizon, (b) plants sensitive to Al-toxicity will be affected unless lime is applied, extraction of soil water may be limited in lower horizon, (c) surface and subsurface-soil deficient in organic carbon which necessitates addition of sufficient quantum of organic manure / matter, (d) comparatively low ability to retain nutrients against leaching, mainly K, Ca and Mg calling for high dose application of these nutrients with split application of N fertilizers, (e) Medium to high P-fixation capacity and very high levels of P-fertilizer or special P-management practices are to be adopted,(f) K-reserves or available K marginal and requires monitoring through frequent application of K-fertilizers, (g) moisture is very much limited during dry season unless it is irrigated. Planting date should take into account the N-flash at the onset of monsoon and if first rains are sporadic germination problem may occur.

Soils of Kurchiboni developed from mixed parent material (calc-schist/mica schist with detrital material) are situated at 2-3% slope and have been classified as L’C ˆˆ ad (2-3%) to L’C ˆˆ adim (2-3%) which characterizes - a) Gravelly (15-35% gravel) loam surface soil over gravelly (>35% gravel) clay subsurface horizon, b) sub- surface soil deficient in organic carbon which necessitates addition of sufficient quantum of organic manure/ matter, c) Plant sensitive to Al-toxicity might be affected to a certain degree; otherwise good, d) moisture is limited during dry season unless it is irrigated. Planting date should take into account the N-flash at the onset of monsoon and if first rains are sporadic germination problem may occur and situation is comparatively better than Garbeta soils, e) Low to medium P-fixation capacity, P management may be needed for soil with medium P fixation range. Soils susceptible to severe soil degradation from erosion exposing undesirable sub soil, high priority should be given to erosion control.

Soils of Silda situated at 1-2% slope and developed on mixed parent material same as that of Kurchiboni have been classified as LL vd (1-2%) to LL vdm (1-2%) characterizes (a) Sandy clay loamy surface and clay loam sub -surface soils with <15% gravel, having good water holding capacity, medium infiltration rate of the surface soil (b) sub- surface

soil deficient in organic carbon which necessitates addition of sufficient quantum of organic manure/ matter, (c) clay with shrik swell properties; tillage difficult when soil is too dry or too moist; soil is other-wise good, (d) calcareous at subsurface horizon below 50 cm, non-water soluble P should be avoided in this soil with slightly higher pH and (e) surface soil as of today is good. Soils of Labani situated at 3-4% slope and developed on Phyllite can be placed as L''L^^ dh (3-4%) to L''L^^ dhim (3-4%) which characterizes (a) gravelly surface and sub-surface soil having around 35% of gravel content (b) sub-surface soil deficient in organic carbon which necessitates addition of sufficient quantum of organic manure/ matter, (c) moisture is limited during dry season unless it is irrigated. Planting date should take into account the N-flash at the onset of monsoon and if first rains are sporadic germination problem may occur, (d) low to medium soil acidity but very often liming may not be needed, but to be required only for Al-sensitive crops. (e) P-fixation is sometime high.

Soils of Bara Ara situated at 2-3% slope an developed on meta-amphibolites been classified as L"C' gi (2-3%) to L"C' m (2-3%) which characterizes a) Highly gravelly (>35%) loam over gravelly (15-30%) clay with gleying condition, susceptible to severe soil degradation from erosion exposing undesirable sub soil, high priority should be given to erosion control, low water holding capacity of surface layer soil, otherwise is good, b) sub-surface soil deficient in organic carbon which necessitates addition of sufficient quantum of organic manure/ matter, c) Prolonged saturation with water in soil due to excess rain may cause denitrification loss of N and sometimes needs drainage improvement for certain crops, d) P-fixation capacity is marginal but in places high levels of P-fertilizers application may be required.

Soils of Lal Gutuwa situated at 3-5% slope and developed on granitic-gneiss have been classified as C ^^ C"dheik (3-5%) which characterizes a) highly gravelly (>35%) clayey surface soil over highly gravelly (>35%) clayey sub-surface soil having low water holding capacity and high rate of infiltration, b) Moisture is limited during dry season unless soil is irrigated; if rains are sporadic germination problem may arise, c) Low to medium soil acidity which calls for lime application at certain interval, d) Very low ability to retain plant nutrients against leaching, heavy application of N-fertilizer should be avoided and application of P, Ca, Mg, & N should be in split, e) Low ability to supply K, K- availability should be monitored through frequent application, efforts to be made to meet the imbalance of potential Mg, Ca and K, f) High P-fixation capacity and requires special P management practices. Netarhat soils situated at 8-10% sloppy land developed on basic parent material have been classified as LLgv (8-10%) to LLv (8-10%) which characterizes a) Clay loam surface soil over sandy loam sub-surface soil having infiltration rate on lower side, good holding capacity, Potential high runoff, Soils susceptible to soil degradation from erosion exposing undesirable sub soil, high priority should be given to surface erosion control, b) Good soil moisture regime, c) Clay with shrink swell characrteristics, tillage is difficult only if soil goes very dry and/or wet. Soils of Bagru situated at 0-2% flat plateau and developed on granitic parent material have been classified as LC egiak (0-2%) to LCeik (0-2%) which characterizes a) sandy clay loam surface soil over clayey sub-surface soil having good water holding capacity and medium infiltration rate, b) susceptible to soil degradation from erosion exposing undesirable sub soil, high priority should be given to erosion control, c) Al- sensitive crop might be affected, d) very low ability to retain plant nutrients against leaching, heavy application of N-fertilizer should be avoided and application of P, Ca, Mg, & N should be in split, e) Low ability to supply K, K- availability should be monitored through frequent application, efforts to be made to meet the imbalance of potential Mg, Ca and K, f) Prolonged saturation with water in soil due to excess rain may cause denitrification loss of N and sometimes needs drainage improvement for certain crops, g) High P-fixation capacity and requires special P management practices.

CONCLUSIONS

From the above results it came out that soils developed on varying parent materials and altitude differed widely in respect of characteristics and as a result their SFCC too varied widely which in turn pointed to their different management options for combating various plant growth and production related constraints.

REFERENCES

1. Barrows, H.L. and Simpson, E. C. (1962). An EDTA method for the direct routine determination of calcium and magnesium in soils and plant tissues. Soil Science Society of America Proceedings 26, 443-445.
2. Blair, G.J., Lefroy, R.D.B., Singh, B.P. and Till A. R. (1997) Development and use of a carbon management index to monitor changes in soil C pool size and turnover rate. In Driven Nature: Plant Litter Quality and Decomposition (G. Cadisch and K.E. Giller, Eds.), pp. 273-281. CAB International, Wallingford, UK.
3. Buol, S. W., Sanchez, P. A., Cate, R.B. and Granger, M.A. (1975) Soil fertility capability classification. In Soil Management in Tropical America (E. Bornemisza and A. Alvarado, Eds.), pp. 126-141. North Carolina State University, Raleigh.
4. Buol, S.W. (1986) Fertility capability classification system and its utilization. Soil Management under Humid Conditions in Asia and Pacific. ASIALAND, IBSRAM, Bangkok, pp. 318-331.
5. Buol, S.W. and Couto, W. (1981) Soil fertility capability assessment for use in the humid tropics. In Characterization of Soils in Relation to their Management for Crop Production: Examples from the Humid Tropics (D.J. Greenland, Ed.) pp. 254-261. Clarendon press, London.
6. Denton, H.P., Peedin, G.F., Hawks, S.N. and Boul, S.W. (1987) Relating the fertility capability classification syatem to tobacco response to potassium fertilization. Soil Science Society of America Journal 51, 1224-1228.
7. FAO (1996) Guidelines for Soil Profile Description. FAO, Rome.
8. Geissen, V., Sanchez-Hernandeza, R., Kampichlerb, C., Ramos-Reyesa, R., and Sepulveda-Lozadaa, A. (2009) Effects of land-use change on some properties of tropical soil – An example from Southeast Mexico. Geoderma 151, 87-97.
9. Hassink, J. (1997) The xapacity of soils to preserve organic C and N by their association with clay and silt particles. Plant and Soil 191, 77-87.
10. Jackson, M.L. (1967) Soil Chemical Analysis. Asia Publishing House, New Delhi.
11. Niyogi, D. 1987. Stepped erosion surfaces of chotonagpur platau fringe. A technical note, published by IIT; Kharagpur.
12. Piper, C. S (1966) Soil and Plant Analysis. Hans Publishers, Bombay.
13. Rao, D.V.K.N. and Jose, A.I. (2003) Fertility capability classification of some soils under rubber in Kerala. Journal of the Indian Society of Soil 51, 183-188.
14. Richards, L. A. (1954) Diagnosis and Improvement of Saline and Alkali Soils. USDA Handbook No. 60, Washington, USA.

15. Sanchez, P. A., Palm, C. A. and Buol, S. W. (2003) Fertility capability soil classification: a tool to help assess soil quality in the tropics. Geoderma 114, 157-185

16. Sanchez, P.A. (1997) Changing tropical soil fertility paradigms; from Brazil to Africa and back. In Plant-Soil Interactions at Low pH (A.C. Moniz *et al.*, Eds.), pp. 19-28. Brazilian Society of Soil Science, Piracicaba, SP.

17. Sanchez, P.A., Couto, W. and Buol, S.W. (1982) The Fertility capability soil classification system: interpretation, applicability and modification. Geoderma 27, 283-309.

18. Soil Survey Staff (1999) Soil Taxonomy, a basic system of soil classification for making and interpreting soil surveys. USDA Agricultural Handbook, 2nd Ed. Natural Resources conservation, Vol. 436, 86 p. US Department of Agriculture, Washington.

19. Van Noordwijik, M., Cerri, C., Woomer, P.L., Nugroho, K. and Bernoux, M. (1997) Soil organic carbon dynamics in the humid tropical forest zone. Geoderma 79, 187-225.

20. Walkley, A. and Black, I. A. (1934) An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science 37, 29-38

21. Zehetner, F and Miller, W. P. (2006) Soil variations along a climatic gradient in an Andean agro-ecosystem. Geoderma 137, 126-134.

APPENDICES

Table 1 (A): Physical and Physicochemical Properties in Relation to SFCC for Soils Developed on Varying Parent Materials at Different Elevations

Name of Soils with Altitude (m)	Parent Material	Depth (cm)	Gravel %	Particle Size (%) (< 2 mm)			Texture (< 2 mm)	Colour (Dry)	pH (1:2.5)	EC(1:2.5) (ds m-1)
				Sand	Silt	Clay				
Kharagpur (50)	Alluvium	A*	---	61.5	13.3	25.2	SCL	2.5 Y7/4	5.20	0.052
		B*	----	55.7	12.3	32.0	SCL	2.5 Y 7/4	4.60	0.024
Garbeta (150)	Alternate cross-bedded sandstone and shale	A	50.5	70.4	8.9	20.7	SCL	2.5 YR 3/4	5.10	0.035
		B	45.8	72.8	5.9	21.3	SCL	5 YR 6/8	4.10	0.012
Kurchiboni (215)	Calc-schist admixed with detrital laterized Material	A	15.4	38.5	33.7	27.8	L	7.5 YR 5/6	4.20	0.158
		B	48.4	41.0	13.9	45.1	C	2.5 YR 3/2	4.90	0.025
Silda (234)	Basic/ Calc-schist	A	11.8	47.7	27.2	25.1	SCL	10 YR 6/6	5.40	0.019
		B	10.3	40.7	22.2	37.1	CL	10 YR 6/6	6.00	0.060
Labani (245)	Phyllite	A	37.6	45.1	32.5	22.4	L	5 YR 4/6	5.20	0.022
		B	41.2	53.8	18.5	27.7	SCL	5 YR 5/6	5.70	0.017
Bra Ara (275)	Meta-amphibolites	A	43.0	36.0	28.5	35.5	CL	5YR 3/3	6.60	0.384
		B	34.7	23.2	36.1	40.7	C	5 YR 3/3	6.20	0.011
Lal gutuwa (590)	Granitic-gneiss	A	70.2	14.8	39.9	45.3	C	2.5 YR 2/4	5.70	0.019
		B	66.2	30.7	24.1	45.2	C	2.5 YR 2/4	5.40	0.053
Netarhat (1037)	Basic (Deccan trap)	A	0.50	40.5	29.5	30.0	CL	2.5 YR 4/6	6.40	0.032
		B	-	52.2	29.0	18.8	SL	10 R 6/8	6.45	0.029
Bagru (1050)	Granite	A	3.2	44.6	27.0	28.4	SCL	7.5 YR 4/4	5.50	0.167
		B	-	23.7	26.3	50.0	C	2.5 YR 5/8	5.8	0.029

NB: For all the soils mean value of each parameter was included in the table

A* = 0-20 cm, B* = 20-50 cm,

SCL, CL, SL, L and C denote Sandy Clay Loam, Clay Loam, Sandy Loam, Loam and Clay, respectively.

Table 1 (B): Chemical Properties in Relation to SFCC for Soils Developed on Varying Parent Materials at Different Elevations

Name of soils with Altitude (m)	Depth (cm)	Exchangeable cations [cmol (p^+) kg^{-1}]				CEC [cmol (p^+) kg^{-1}]	ESP	SOC (g kg^{-1})	Total Exchange Acidity [cmol (p^+) kg^{-1}]	Aluminum acidity [cmol (p^+) kg^{-1}]	Exchangeable H^+ acidity [cmol (p^+) kg^{-1}]
		Ca^{2+}	Mg^{2+}	Na^+	K^+						
Kharagpur (50)	A*	3.95	2.45	0.15	0.20	12.2	2.2	3.4	1.17	0.05	1.12
	B*	1.85	1.25	0.09	0.18	9.0	2.7	1.4	4.55	2.80	1.75
Garbeta (150)	A	2.30	1.20	0.10	0.33	7.8	2.5	3.2	3.70	1.60	2.10
	B	1.22	0.35	0.10	0.25	5.9	5.2	2.5	4.40	3.90	0.50
Kurchiboni (215)	A	0.80	0.50	Trace	0.25	11.2	Neg.	9.0	6.15	3.20	2.95
	B	2.20	0.80	0.10	0.10	10.0	3.1	3.6	4.30	1.20	3.10
Silda (234)	A	5.12	3.20	Trace	0.28	19.0	Neg.	6.6	3.57	Nil	3.57
	B	5.80	3.80	Trace	0.35	38.0	Neg.	3.3	Nil	Nill	Nill
Labani (245)	A	1.50	1.10	0.10	0.35	8.0	3.3	7.8	3.02	0.05	2.97
	B	2.10	1.30	Trace	0.20	8.5	Neg.	4.2	2.35	Nill	2.35
Bra Ara (275)	A	5.50	2.90	Trace	0.18	20.1	Neg.	6.9	3.52	Nill	3.52
	B	8.90	7.90	0.10	0.15	33.0	0.6	3.6	4.76	Nill	4.76
Lal gutuwa (590)	A	0.20	0.10	Trace	0.10	4.3	Neg.	9.4	0.71	Nill	0.71
	B	0.20	Trace	Trace	0.08	3.2	Neg.	7.0	0.62	Nill	0.62
Netarhat (1037)	A	12.20	6.10	0.20	0.42	32.2	1.1	15.8	4.96	Nill	Nill
	B	10.30	3.30	0.10	0.51	23.0	0.7	7.2	1.77	Nill	Nill
Bagru (1050)	A	0.50	0.20	Trace	0.15	5.2	Neg.	13.4	2.16	0.20	1.96
	B	0.80	0.10	Trace	0.12	6.3	Neg.	8.2	2.11	Nill	2.11

NB : For all the soils mean value of each parameter was included in the table

A* = 0-20 cm, B* = 20-50 cm,

Table 2: Type, Substatas Type, Condition Modifiers for Soil Fertility Capability Classification (SFCC)

Soils at Varying Altitude (m)	Type	Substrata	Modifiers Type	Check List									SFCC Unit
				g	d	e	a	i	h	k	v	m	
Kharagpur (50)	L	L	aeihm /			*	*	*	*			*	LLaeihm (0-2%) to
			aikm				*	*		*		*	LLaikm (0-2%)
Garbeta (150)	L ^^	L ^^	adeim /		*	*	*	*				*	L"L ^^ adeim (3-4%) to
			adeikm		*	*	*	*		*		*	L"L ^^ adeikm (3-4%)
Kurchiboni (215)	L^	C ^^	ad /		*		*						L'C ^^ ad (2-3%) to L'C ^^
			adim		*		*	*				*	adim (2-3%)
Silda (234)	L	L	vd /		*						*		LL vd (1-2%) to LL vm (1-
			vdm		*						*	*	2%)
Labani (245)	L ^^	L ^^	dh /		*				*				L"L ^^ dh (3-4%) to
			dhim		*			*	*			*	L"L ^^ dhim (3-4%)
Bara Ara (275)	L^^	C^	gi /	*				*					L"C' gi (2-3%) to L"C' m
			m									*	(2-3%)
Lal gutuwa (590)	C^^	C"	Dheik		*	*		*	*	*			C ^^ C"dheik (3-5%)
Netarhat (1037)	L	L	gv /	*							*		LLgv (8-10%) to LLv (8-
			v								*		10%)
Bagru (1050)	L	C	egiak /	*		*	*	*		*			LCegiak (0-2%) to LCeik
			eik			*		*		*			(0-2%)

N. B. Modifiers type, check list are mentioned for 0-20 and 20-50 cm Scperately and accordingly SFCC unit are mentioned as range.

Table 3: Description of the Soil Fertility Capability Classification (SFCC) Unit and Their Comparison with Soil Taxonomy

Soils at Varying Altitude (m)	Taxonomic Classification	SFCC Unit	Modifiers Type
Kharagpur (50)	Loamy, mixed, Ultic Haplustalf	LLaeihm (0-2%) to LLaikm (0-2%)	Sandy clay loamy surface and subsurface-soils, dry, having low CEC and high P- fixation capacity. Soils are acidic with occasional aluminum toxicity, deficient in organic carbon and occasionally deficient in K. Soil situated at 0-2% slope.
Garbeta (150)	Sandy- skeletal, mixed, Kanhaplic Haplustult	L''L ''adeim (3-4%) to L''L'' adeikm (3-4%)	Gravelly sandy clay loamy surface and sub -surface soils, dry soils with low CEC, high P- fixation capacity, deficient in organic carbon, aluminum toxicity and occasionally deficient in K. Soil situated at 3-4% slope.

Table 3: Contd.,

Kurchiboni (215)	Clayey –skeletal, mixed, Oxic Rhodustalf	L’C ''ad (2-3%) to L’C''adim (2-3%)	Gravelly loamy surface over highly gravelly loamy sub surface, dry soils, susceptible to severe soil degradation from erosion exposing undesirable sub soil, high priority should be given to erosion control, occasional aluminum toxicity with high P- fixation capacity, sub-soil deficient in organic carbon. Soil situated at 2-3% slope.
Silda (234)	Fine, smectitic, Typic Chromustert	LL vd (1-2%) to LLvm (1-2%)	Sandy clay loamy surface and clay loam sub -surface soils, dry soils with sticky and plastic clay > 50% of 2:1 expanding clays with shrinking and swelling nature. Sub-soil deficient in organic carbon. Soil situated at 1-2% slope.
Labani (245)	Loamy-skeletal, mixed Ultic Haplustalf	L’’L ˆˆ dh (3-4%) to L’’Lˆˆ dhim (3-4%)	Highly gravelly sandy surface and sub- surface soils, dry soils acidic in reaction, occasional high P- fixation capacity, sub-soil deficient in organic carbon. Soil situated at 3-4% slope.
Bara Ara (275)	Ashy- skeletal, montmorillonitic ,Andic Eutropept	L”C’ gi (2-3%) to L”C’m (2-3%)	Highly gravelly loam over gravelly clay with gleying condition, susceptible to severe soil degradation from erosion exposing undesirable sub soil, high priority should be given to erosion control, neutral in soil reaction. High P- fixation capacity of surface soil and sub-soil deficient in organic carbon. Soil situated at 2-3% slope.
Lal gutuwa (590)	Clayey- skeletal, kaolinitic Oxic Rhodustult	C” C” dheik (3-5%)	Loamy surface over highly gravelly loamy soil, dry acidic in soil reaction, low CEC and high P- fixation capacity and deficient in K. Soil situated at 3-5% slope.
Netarhat (1037)	Loamy, montmorillonitic, Vertic Eutropept	LLgv (8-10%) to LLv (8-10%)	Loamy surface and sub- surface soils with gleying surface soil condition, sticky and plastic clay > 50% of 2:1 expanding clays with shrinking and swelling nature and situated at 8-10% sloppy land
Bagru (1050)	fine-loamy / Clayey, mixed, Typic Kandiustult	LCegiak (0-2%) to LCeik (0-2%)	Loamy surface and clayey sub- surface soil, susceptible to severe soil degradation from erosion exposing undesirable sub soil, high priority should be given to erosion control, low CEC, gleying surface soil condition, high P- fixation capacity and aluminum toxicity, deficient in K.